STUDIES OF BEAM POSITION STABILITY IN SOLEIL STORAGE RING

P. Nghiem*, J.-L. Laclare*, M.-P. Level*°, A. Loulergue+, A. Nadji*°, J. Payet+

*SOLEIL, DRIF du CNRS, Av. de La-Terrasse, Bât. 5, 91198 Gif/Yvette Cedex France
+CEA/DSM/DAPNIA/SEA, LNS, 91191 Gif/Yvette Cedex France
°LURE, Centre Universitaire de Paris Sud, Bât. 209 A, 91898 Orsay Cedex France

Abstract

The SOLEIL high brilliance is obtained by means of very low beam emittances which can result in vertical source sizes down to 6 microns at insertion device location. The effective beam size and thus the brilliance would be spoiled if the beam position stability were not excellent. We derive simple analytical formulae to calculate the statistical effects of external sources of vibrations propagating as plane waves in the soil to the individually supported magnets. We also consider in-situ sources of vibrations acting on girders supporting a series of magnets. The tolerances on the source amplitudes are then determined.

1. INTRODUCTION

To reach the high brilliance objective of SOLEIL, one has to design a strong focusing optics where the beam emittance together with the beam size at insertion devices must be very low. These design performances would be deteriorated in the real situation if the beam position was not stable because of numerous noise sources surrounding the machine. The problem is very crucial because the electron beam has a micrometric size and the beam motion is strongly amplified from magnet displacements. It is therefore necessary to study the series noise source - magnet displacement - closed orbit (C.O.) motion - beam size and emittance variations.

For this study, we suppose that no feedback correction system is used and we only take into account the quadrupole motion, because their contribution is the main one and thus induces the most stringent tolerances. First of all, we determine the tolerated optics deteriorations and the related C.O. motion. The behaviour differences following two time constant ranges are discussed. Then we calculate, in the presence of girders or not, the effects on C.O. of two types of noise sources : random in-situ noise sources and external plane wave. Finally, the tolerances on ground vibration amplitudes are given for each case.

[1] Work supported by CNRS, CEA, MENESR.

2. TOLERATED PERFORMANCE DETERIORATIONS

The enlargement of effective beam size and beam divergence usually tolerated are :

$$\frac{\Delta\sigma_{eff}}{\sigma_o} = 0.1 \text{ and } \frac{\Delta\sigma'_{eff}}{\sigma'_o} = 0.1 \qquad (1)$$

where σ means the rms. value. The corresponding emittance enlargement is

$$\frac{\Delta\varepsilon_{eff}}{\varepsilon o} = 0.2 \qquad (2)$$

At this point one must distinguish two situations :

• Slow motion, that is the C.O. motion is slower than the data acquisition time of radiation users. The effective beam dimensions result from the linear sums :

$$\sigma_{eff} = \sigma_o + \sigma_{C.O.} \text{ and } \sigma'_{eff} = \sigma'_o + \sigma'_{C.O.} \qquad (3)$$

and conditions (1) imply

$$\frac{\sigma_{C.O.}}{\sigma_o} = 0.1 \text{ and } \frac{\sigma'_{C.O.}}{\sigma'_o} = 0.1 \qquad (4)$$

• Fast motion, that is the C.O. motion is faster than the user observation time. The beam image is blurred and the effective beam dimensions are this time determined by the quadratic sums :

$$\sigma^2_{eff} = \sigma^2_o + \sigma^2_{C.O.} \text{ and } \sigma'^2_{eff} = \sigma'^2_o + \sigma'^2_{C.O.} \qquad (5)$$

Conditions (1) become

$$\frac{\sigma_{C.O.}}{\sigma_o} = 0.45 \text{ and } \frac{\sigma'_{C.O.}}{\sigma'_o} = 0.45 \qquad (6)$$

3. EFFECTS OF SURROUNDING NOISES ON C.O.

3.1. General hypothesis

The SOLEIL standard optics (Fig. 1) is considered, where the dispersion function is non zero everywhere to lower the emittance down to 3.0 nm.rad. The vertical/horizontal coupling factor is at its nominal value of 0.01.

The effects of surrounding noises on C.O. depend on the amplification coming from quadrupole motion :

$$\sigma_{C.O.} = A\sigma_Q \qquad (7)$$

In principle one has to study these effects for every photon source point. In the present report, as the final aim is to calculate the tolerances on quadrupole displacement for satisfying conditions (4) or (6), that is

$$\sigma_Q \propto \frac{\sigma_o}{A} \text{ or } \frac{\sigma'_o}{A'} \quad (8)$$

one can simply consider for example the medium length straight sections of the ring. The reason is that :

- in the vertical plane, (8) is nearly independent of the azimuth, the betatron phase contribution being very small
- in the horizontal plane, (8) depends furthermore on the dispersion function, but it only has a sense when calculated for insertion device sources, and in our case the dispersion has about the same value in different straight sections.

So the beam dimensions at the middle of the concerned straights are :

	Horizontal	Vertical
σ_O	169 µm	6 µm
σ'_O	27 µrad	5 µrad

3.2. The use of girders

As one can see, the tolerances σ_Q depend on the amplification factors A or A' which are governed by the fact that the quadrupoles can move independently or coherently. Indeed, for our case of a Chasman-Green-like optics, when :

- a series of quadrupoles is supported by a girder,
- the motion of the girder can be reduced to a pure translation one, without any rotation nor deformation,
- there is no quadrupole motion with respect to the girder

the correlated displacements of focalising and defocalising quadrupoles will partially compensate their effects on the C. O.

For SOLEIL, when every triplet and quadruplet is rigidly fixed to a common girder, the decreasing of A or A' is very important, as compared to when the quadrupoles are individually supported, specially in the vertical plane :

	Horizontal	Vertical
Without girder (A/A')	29.2 / 7.0	9.05 / 8.6
With girder (A/A')	16.4 / 4.0	1.63 / 1.5
A or A' decreasing	44 %	82 %

Note : The amplification factors are calculated for random motion of quadrupoles or girders.

To effectively reach these benefits, the design of the girder has to take care of the problems generated by thermal deformations or vibration eigen modes.

A last point remaining to be specified is that for the present optics, we always have

$$\frac{\sigma'_o}{A'} < \frac{\sigma_o}{A} \quad (9)$$

so from now on we will only refer to the conditions related to beam divergence.

3.3. Random in-situ noise sources

In the machine site surroundings, human activities, mechanical devices, water cooling or thermal drifts act as random noise sources and generate uncorrelated motions of different parts of the ring.

When the perturbation time constant is slower than the data acquisition time of users, that is for thermal drifts or multiple low frequency local sources, we are in the situation of conditions (4), and equations (8) give the following tolerances :

	Horizontal	Vertical
Without girder	σ_Q = 0.39 µm	σ_Q = 0.06 µm
With girder	σ_Q = 0.69 µm	σ_Q = 0.33 µm

For a high frequency noise source where the wavelength is enough short so that every part of the ring can be supposed to move independently from each other, the perturbation time constant is faster than the data acquisition time, conditions (6) must be applied and the tolerances for ground vibration amplitudes are a factor 4.5 less severe than the previous ones :

	Horizontal	Vertical
Without girder	σ_Q = 1.7 µm	σ_Q = 0.26 µm
With girder	σ_Q = 3.1 µm	σ_Q = 1.5 µm

3.4. Long wavelength external plane waves

Vibrations come also from external sources located far from the machine site. As the short wavelengths are strongly damped by the ground, these long distance waves are featured by long wavelengths and induce a correlated motion between different parts of the ring which can come into resonance with the betatron oscillation. One can expect that in such a situation, the presence or not of girders doesn't play a role. When the frequency is below about 5 Hz there is no perturbation because the corresponding wavelength is larger than the machine diameter (107 m). As usually the time constant of user experiments is larger than few tenth of seconds, it means that we are in the case called above fast motion and the constraint on emittance deterioration is :

$$\frac{\Delta\varepsilon_{eff}}{\varepsilon_o} = \frac{\varepsilon_{C.O.}}{\varepsilon_o} = 0.2 \quad (10)$$

For the vertical motion, $\varepsilon_{C.O.}$ is linked to the peak wave amplitude $\hat{z}$ by [1] :

$$\varepsilon_{C.O.} = \left(\frac{\hat{Z}}{2\sin\pi\nu}\right)^2 \left[a_{cc}^2 + a_{cs}^2 + a_{sc}^2 + a_{ss}^2\right]$$

with (11)

$$a_{cc} = \sum_Q \mu_Q \cos A \cos B, \quad a_{cs} = \sum_Q \mu_Q \cos A \sin B$$

$$a_{sc} = \sum_Q \mu_Q \sin A \cos B, \quad a_{ss} = \sum_Q \mu_Q \sin A \sin B$$

$$A = C\lambda^{-1}\cos(\theta_Q - \theta_w), \quad B = \phi_Q - \pi\nu$$

$$\mu_Q = K_Q l_Q \sqrt{\beta_Q}$$

where C is the ring circumference, λ the wavelength, θ_w the wave incident angle, K_Q l_Q, β_Q, ϕ_Q and θ_Q, the integral gradient, beta, functions and angular position related to quadrupoles.

$\hat{Z}$ can thus be determined for satisfying condition (10). Fig. 2 shows the curve of $\hat{Z}$ versus the frequency F for two examples of sites having different propagation speeds v. The tolerances for the vertical wave amplitude, for the usual frequency range below 50 Hz is :

	v	F	$\lambda = v/F$	$\hat{Z}$
Soft site	500 m/s	[5 ; 50] Hz	[100 ; 10] m	[±3.2 ; ±0.8]µm
Rock site	2500 m/s	[25 ; 50] Hz	[100 ; 50] m	[±3.2 ; ±2.0]µm

CONCLUSION

The use of girders is very beneficial for the beam stability at the condition that there is no amplification coming from themselves or the pedestals. The random motion slower than user observation time dictates the most severe constraint. One expect that the tolerances given above can be satisfied with a special care in the design of the vacuum chamber, the tunnel air conditioning, the cooling water, etc. [2]. Nevertheless, a slow feedback correction system is planned and if necessary a dynamic one up to 100 Hz could be installed.

REFERENCES

[1] A. Nadji, to be published.

[2] M.-P. Level et al., this conference (MOP10F).

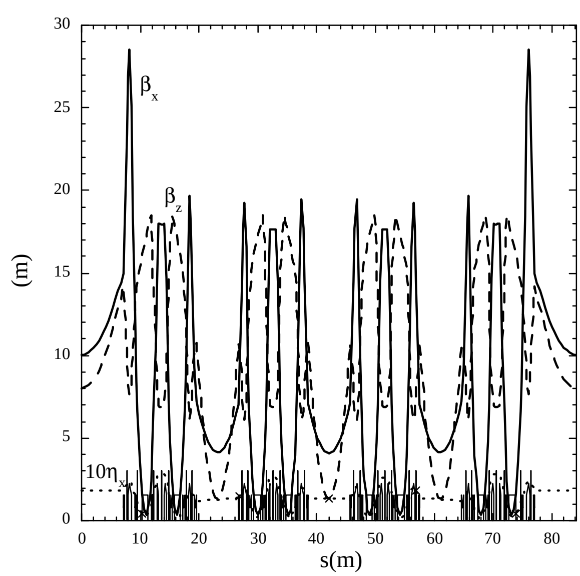

Fig. 1. Optical functions.

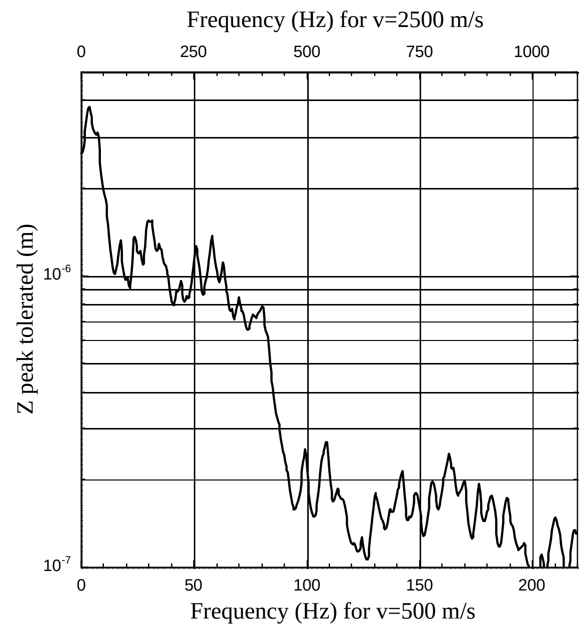

Fig. 2. $\hat{Z}$ peak tolerated.